CAB INTERNATIONAL
MYCOLOGICAL INSTITUTE
LIBRARY
4 FEB 1992
FROMME, F. D

Va. (Blacksburg)–3

VARIETAL SUSCEPTIBILITY OF BEANS TO RUST 1921

BY

F. D. FROMME AND S. A. WINGARD

Reprinted from JOURNAL OF AGRICULTURAL RESEARCH
Vol. XXI, No. 6 : : : : : Washington, D. C., June 15, 1921

IMPERIAL BUREAU OF MYCOLOGY

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE, WITH
THE COOPERATION OF THE ASSOCIATION OF LAND-GRANT COLLEGES

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

VARIETAL SUSCEPTIBILITY OF BEANS TO RUST [1]

By F. D. FROMME, *Plant Pathologist*, and S. A. WINGARD, *Assistant Plant Pathologist*, *Virginia Agricultural Experiment Station*

INTRODUCTION

The bean rust fungus, *Uromyces appendiculatus* (Pers.) Fries, is worldwide in distribution, being found practically coextensive with the distribution of its hosts throughout the North American continent and in the West Indies, South America, Europe, Africa, Asia, Japan, and Australia. In addition to its common host, *Phaseolus vulgaris* L., it occurs in North America on ten species of Phaseolus, two species of Dolichos, two of Strophostyles, and three of Vigna (*1*).[2] It is an autoecious species with the full complement of spore forms. The aecia are of the cupulate type and are of rather rare occurrence, judging from the collections in herbaria. The writers have seen them in the field on only one occasion. The uredinia and telia are found during the summer and fall and are very common. The relative importance of the different spore forms in the overwintering of the rust has not been determined, but it seems likely that the teliospores are of minor importance, at least under Virginia conditions, and that the urediniospores are the most important factor in overwintering.

In the opinion of the writers bean rust is commonly underrated as a limiting factor in bean production. The losses are indirect, being occasioned by decreased vigor due to foliage injury, and this fact tends to obscure the amount of curtailment of yield except in very severe cases. Although the disease occurs in all parts of the United States losses seem to be especially severe in Virginia, West Virginia, Tennessee, and southern Ohio of the eastern States, in Georgia and Louisiana of the southern States, and in California. In the commercial bean areas of the North it seemingly appears too late as a rule to cause much injury. It is occasionally severe in the New England States. In Virginia bean rust is one of the chief limiting factors in production. Severe injury is commonly found on three varieties, Kentucky Wonder, Navy Pea, and Tennessee Green Pod. Evidence of the severity of bean rust in California and of the inefficacy of spraying may be seen in the following quotations. R. E. Smith (*10*) in discussing the work at the California Experiment Station says:

Mr. Rogers did a considerable amount of work during the year in an endeavor to find means for checking a serious rust (*Uromyces appendiculatus*) which attacks the

[1] Published with the approval of the Director of the Virginia Agricultural Experiment Station. Paper 56 from the Department of Plant Pathology and Bacteriology.

[2] Reference is made by number (italic) to "Literature cited," p. 404.

Journal of Agricultural Research,
Washington, D. C.
yc

Vol. XXI, No. 6
June 15, 1921
Key No. Va. (Blacksburg)-3

Kentucky Wonder bean in San Diego county and prevents the growing of this valuable crop late in the fall. Treatment both with Bordeaux mixture and finely ground sulfur was tried, but unfortunately neither material gave any appreciable control of the disease.

D. C. Milbrath [1] is quoted as follows:

In Los Angeles county, especially in the San Gabriel Valley, rust developed so rapidly on beans during the past week that some fields have been abandoned. This is the case particularly with Lady Washington and French varieties.

Until recently there has been little specific information in literature on the relative susceptibility of bean varieties to rust.

Duggar (*2*) states that great differences exist in the susceptibility of varieties among both dwarf and pole sorts and suggests that the selection of resistant varieties would seem to be possible.

Gassner (*5*) noted a difference in the susceptibility of 2 varieties of beans in South America and later planted 15 varieties in a field test. These were inoculated with rust spores, and wide variations in susceptibility were seen. Three of the varieties were severely injured, while the remainder were only moderately, slightly, or not at all affected.

Jordi (*7*), in Europe, took field records on five varieties of pole beans with respect to severity of rust, using the cipher 1–10 to indicate the state of susceptibility. Four of the varieties were susceptible, being rated 7–10, while one, Klosterfrauen, was resistant, being rated only 0.5–1.

In the Plant Disease Bulletin for September 15, 1918, W. J. Morse (*9*) lists 17 varieties of beans with respect to their susceptibility to rust in Maine. Seven of the varieties were severely attacked, while the other 10 developed only slight infection or none.

In a previous publication (*4*) the writers have described the field behavior of a large number of bean varieties with respect to their susceptibility to rust. Very marked variations were found together with great curtailment of productivity, some of the most susceptible varieties being complete failures.

It is the purpose in this paper to describe more fully the various phenomena found in studies of rust infection and development on certain varieties of beans, especially under greenhouse conditions.

EXPERIMENTAL METHODS

Considerable preliminary work was devoted to the development of a technic. A standard dosage, method of inoculation, and uniformity in the records of infection were recognized as some of the first requisites. One of the greatest difficulties in this connection lies in the material itself. The pathogene, together with other Uredinales, can not be grown apart from the living host, and in consequence the pure culture

[1] MILBRATH, D. C. [FIELD NOTES.] *In* U. S. Dept. Agr. Bur. Plant Indus. Off. Cotton, Truck, Forage Crop Disease Inves. News Notes, v. 7, no. 22, p. 5. 1918. Mimeographed.

standards of the bacteriologist can only be approximated. The strain of the fungus used in the experimental work to be discussed was obtained from Kentucky Wonder beans in a garden at Blacksburg in the fall of 1917. In an effort to obtain a single spore strain, bean plants were inoculated sparingly with urediniospores, and only a few well-isolated sori were obtained. Urediniospores from a single sorus were used again for a sparing inoculation on other plants. The repetition of this procedure through several spore generations provided a strain which could, with reasonable certainty, be considered to have arisen from a single urediniospore. Stock cultures of this strain were maintained on plants of Tennessee Green Pod, and all of the inoculum used was taken from this variety.

The method of inoculation used throughout the work consisted in the atomization of the host with a urediniospore suspension followed by incubation in a moist chamber for 24 hours. One of the authors (*3*) in studies with the crownrust of oats had found that the best infection was obtained when dry spores from a culture of rusted oat seedlings were allowed to fall on plants which had been previously atomized with water. Melhus and Durrell (*8*) have also found dusting the spores on the moistened plants preferable to the use of spore suspensions. They have found a considerable reduction in the percentage of germination of urediniospores of this rust after passing them through an atomizer. There seems, however, to be greater probability of securing uniformity of dosage with spore suspensions, and this method has, therefore, been followed in our work.

A standard dosage was used throughout the experiments, the inoculum for each plant being the spores from one mature uredinium, grown on Tennessee Green Pod, applied in 1 cc. of water. In practice 40 plants were inoculated at one time, the dosage being the urediniospores from 40 sori in 40 cc. of water.

Since it had been determined previously that the susceptibility of the bean leaf varies somewhat according to the degree of maturity, the inoculations were made with the plants in as near the same stage of development as possible, the rule followed being to select the time when the first trifoliate leaf had reached a length of about ½ inch. At this time the primordial leaves have attained practically their full size but are still young and in a susceptible state. The number of days required to reach this stage of development from the planting of the seed varies with the conditions in the greenhouse between 11 and 20 days, averaging about 14 days.

In order to secure uniformity of exposure to infection an inoculation frame is employed to hold 40 four-inch pots each of which contains a single bean plant. Four varieties are inoculated in each test, 10 plants to a variety, the varieties being distributed through the frame in such a

manner as to overcome any inequality in inoculation. Plate 69, A, shows the frame filled in preparation for inoculation. The inoculum, as stated previously, is applied with an atomizer, all plants receiving as nearly as possible the same amount of material. A very fair degree of uniformity in the resultant infection is obtained as a rule by this method throughout the 10 plants of a variety. The results of one test are shown in Table I.

TABLE I.—*Experiment No. 29. Results of inoculation of four varieties of beans planted December 9 and inoculated December 31 at the rate of one sorus per plant; sori visible January 8, sporulating January 10; count made January 17*

Plant No.	Tennessee Green Pod.						McCaslan.					
	Leaf No. 1.			Leaf No. 2.			Leaf No. 1.			Leaf No. 2.		
	Number of sori.	Number of flecks.	Area.	Number of sori.	Number of flecks.	Area.	Number of sori.	Number of flecks.	Area.	Number of sori.	Number of flecks.	Area.
			Square inches.			*Square inches.*			*Square inches.*			*Square inches.*
1	206		8.73	213		8.47	452		10.64	194		9.37
2	134		5.32	86		5.19	310		8.53	319		7.90
3	180		6.33	90		6.14	225		10.60	281		9.52
4	299		6.00	269		5.17	205		5.23	221		5.72
5	132		5.98	209		5.47	142		5.35	163		4.95
6	337		6.23	156		6.03	400		6.60	191		5.97
7	113		5.30	247		5.96	286		6.98	257		7.03
8	245		6.10	240		6.63	278		6.00	302		6.40
9	102		3.98	178		4.55	356		5.40	352		5.60
10	132		4.47	144		4.29	263		6.80	134		6.20
Total	1,880		58.44	1,832		57.90	2,917		72.13	2,414		68.66

Plant No.	Improved Goddard.						Dwarf Black.					
	Leaf No. 1.			Leaf No. 2.			Leaf No. 1.			Leaf No. 2.		
	Number of sori.	Number of flecks.	Area.	Number of sori.	Number of flecks.	Area.	Number of sori.	Number of flecks.	Area.	Number of sori.	Number of flecks.	Area.
			Square inches.			*Square inches.*			*Square inches.*			*Square inches.*
1		196	10.90		158	11.80	44	42	4.57	26	25	4.40
2		140	10.78		78	12.00	47	39	7.70	36	30	7.69
3		76	8.78		82	8.97	47	39	4.50	47	19	5.69
4		106	9.45		53	10.40	50	17	3.75	17	9	3.90
5		148	13.79		137	14.13	9	3	5.68	31	12	4.43
6		118	11.55		179	12.15	30	28	4.15	10	4	4.60
7		136	11.37		93	10.55	10	10	4.93	14	16	3.94
8		71	13.85		179	13.90	31	20	7.10	65	22	6.75
9		91	9.86		92	9.70	49	31	5.80	41	34	6.35
10		139	15.50		139	15.54	36	32	5.07	28	20	5.04
Total		1,221	115.83		1,190	119.14	353	261	53.25	315	191	52.79

TABLE II.—*Summary of experiment No. 29. Percentage of total infection and fertile infection in terms of Tennessee Green Pod, which is taken as the standard and rated 100 per cent*

	Tennessee Green Pod.	McCaslan.	Improved Goddard.	Dwarf Black.
Total number of sori on 20 leaves	3,712	5,331	.....	668
Total number of flecks on 20 leaves	.....	.....	2,411	452
Total number of infections on 20 leaves	3,712	5,331	2,411	1,120
Total area in square inches	116.34	140.79	234.97	106.04
Number of sori per square inch	31.91	37.87	.....	6.30
Number of flecks per square inch	.....	.....	10.26	4.26
Number of infections per square inch	31.91	37.87	10.26	10.56
Percentage of total infection	100.00	118.68	32.15	33.09
Percentage of fertile infection	100.00	118.68	.....	19.74
Percentage of abortive infection [1]	.....	.....	100.00	40.36

[1] Calculated from total infection on each variety separately.

Following inoculation the plants are removed to a moist chamber large enough to hold all 40 plants. They are kept here in a humid atmosphere for 24 hours and are then set on the greenhouse bench. The incubation period varied within limits of 8 to 14 days during the tests, the average time from inoculation to the rupture of the sorus being 10 days. The sori are visible two or more days prior to sporulation. The final data on infection are secured 7 days after sporulation begins. This permits a full development of the initial infection on all varieties but comes early enough to exclude secondary sori which develop around the primary sorus in the more susceptible varieties (Pl. 71, B). At this time the primordial leaves are removed from the plants and the number of infections (both sori and flecks) are determined. The typical infection obtained on susceptible varieties is shown on a leaf of Dutch Case Knife in Plate 70, A, and abortive infection or flecking on a leaf of Improved Goddard in Plate 70, B.

A photographic retouching frame has been found a great aid in the counting of infections. The leaves are placed on a glass plate in this frame before an incandescent lamp, and by this lighting it is possible to determine the number of infections on both leaf surfaces at the same time, thus preventing the duplication which would result from separate counts. Infection takes place with equal readiness on both upper and lower surfaces, but with the method of inoculation used the greater number develop on the upper surface. In many cases the sorus breaks through on both surfaces. Before the count is taken the leaf surfaces are brushed with a camel's-hair brush to remove dirt and superfluous spore powder. Following the count the area of the leaf is determined by means of a planimeter, and the number of infections is reduced to a unit area basis in all varieties.

VARIATION IN DEVELOPMENT OF INFECTION

The normal development on the more susceptible varieties, of which Tennessee Green Pod is an example, is described as follows from inoculation made on January 20, 1919. The inoculation was made at 5 p. m., and after 24 hours in the moist chamber the plants were placed on the greenhouse bench. The first evidence of infection was noted 136 hours after inoculation. The sori at this time were very faint indeed, being scarcely visible. In 143 hours they were evident on close examination as minute pale spots. They were quite distinct after 161 hours, had taken on a pale yellow color, and were slightly elevated above the leaf surface. At 183 hours the centers of the sori were orange-red in color, showing sporulation, and were conspiciously elevated. The epidermis had ruptured on some of the larger sori in 190 hours, and the uredinio-spores were exposed. A ring of secondary sori develops around the primary sorus on the more susceptible varieties.

Variations from the normal development are found in a number of varieties. These variations may be listed as follows: (a) production of flecks, (b) production of telia instead of uredinia, or sori containing both uredinio-spores and teliospores, (c) production of uredinia subnormal in size, (d) lengthening of incubation period.

The term fleck is used to indicate an abortive infection. The flecks produced on different varieties vary somewhat in shape and size (Pl. 73, A, B). The flecks which develop on Tennessee Wonder (Pl. 73, C) are seen on both leaf surfaces, but are most conspicious on the lower surface. They are circular in outline, with a slightly irregular border. The spot is concave, the tissue being noticeably shrunken. A definite bronze-brown rim bounds the fleck. This is narrow in some flecks and may extend well toward the center in others. An island of green tissue may remain in the center, and this may protrude slightly, suggesting the beginning of a sorus. In some varieties a small sorus is developed in the center of some of the flecks (Pl. 69, B, *e*, *f*). The flecks on any variety are usually larger than the sori, their average diameter being from two to three times that of the sori.

The development of flecks is characteristic of certain varieties and is considered an indication of resistance. No flecks have ever been seen on Tennessee Green Pod or other very susceptible varieties, but they are regularly produced on certain others, notably Tennessee Wonder, Improved Goddard, and Hodson Green Pod. On some varieties all the infections develop into flecks, while on others there may be a considerable number of normal sori developed and only a few flecks. The percentage of flecking with the different varieties is shown in Table III.

TABLE III.—*Susceptibility of different varieties of beans to rust infection, with infection on Tennessee Green Pod as standard and rated 100 per cent*

BUSH BEANS, GREEN POD

Experiment No.	Variety.	Average leaf area.	Number of infections per square inch.		Percentage of infection.		
			Flecks.	Sori.	Total.	Abortive.	Fertile.
		Square Inches.					
12a	Pink	4.52	.....	9.82	119.61	.....	119.61
27	Snowflake	2.67	.....	38.86	116.31	.....	116.31
27	Navy Pea	2.51	.....	36.92	110.50	.....	110.50
10	Tepary	2.28	.....	7.79	101.43	.....	101.43
5	Pinto	4.43	.....	65.88	89.20	.....	89.20
24	Lady Washington	4.05	1.87	28.76	79.10	6.12	73.83
8	Red Valentine	4.42	.....	55.09	57.29	.....	57.29
31	Blue Pod Navy	3.65	.....	05	43.60	.....	43.60
7	Red Kidney (Wells)	10.58	.....	45.76	39.39	.....	39.39
4	Emerald Beauty	10.47	.56	10.55	38.52	5.04	36.58
20	White Kidney	8.41	.....	11.34	33.35	.....	33.35
21	Burpee's Stringless	6.69	8.10	12.62	53.01	39.05	32.28
7	Full Measure	12.29	.....	37.19	32.01	.....	32.01
15	White Marrow	6.23	.....	2.92	25.15	.....	25.15
19	Warren	11.86	3.16	4.91	32.77	39.19	19.94
9	Horticultural, Dwarf	7.34	7.47	41.37	22.40	15.29	18.97
19	Round Six Weeks	6.86	.....	3.58	14.54	.....	14.54
14	French's Horticultural	8.98	1.15	2.96	16.36	27.91	11.78
18	Bountiful	8.24	1.00	1.69	13.96	36.68	8.77
34	Bird Eye	6.31	.....	.86	8.62	.....	8.62
32	Yellow Eye	9.54	.....	.69	6.97	.....	6.97
10	Longfellow	8.65	.....	.50	6.50	.....	6.50
24	Giant Stringless	7.69	.....	1.94	4.98	.....	4.98
8	Black Valentine	4.88	19.59	1.15	21.57	94.47	1.19
12a	Mexican Red	6.79	.16	.02	2.19	87.50	.24
24	Early Refugee	7.07	.84	.02	2.21	97.52	.05
14	Low's Champion	6.68	1.68	.01	6.73	99.51	.04
29	Improved Goddard	11.75	10.26	.....	32.15	100.00	.....
33	May Queen	6.25	.97	.....	10.83	100.00	.....
18	Early Mohawk	11.86	.95	.....	10.12	100.00	.....
18	Refugee	5.99	1.51	.....	7.83	100.00	.....
30	Hodson Green Pod	12.13	1.14	.....	5.81	100.00	.....

BUSH BEANS, WAX POD

2	Keeney's Rustless	6.97	6.51	12.03	38.89	35.15	25.24
29	Dwarf Black	5.30	4.26	6.30	33.09	40.36	19.74
33	Scarlet Wax	10.13	.66	2.23	15.88	23.11	12.25
2	Currie	8.22	18.78	1.84	43.26	91.09	3.17
23	California	6.38	10.18	.....	63.46	100.00	.....
22	Webber	7.06	12.47	.....	50.71	100.00	.....
22	Flagolet	7.28	12.18	.....	49.53	100.00	.....
26	Crystal White	3.10	5.19	.....	44.24	100.00	.....
23	Challenge	4.91	4.80	.....	29.93	100.00	.....
22	Wardwell	6.65	6.58	.....	26.76	100.00	.....
23	New Pearl	7.56	3.22	.....	20.07	100.00	.....
27	Hodson Wax	6.68	5.88	.....	17.60	100.00	.....
23	Detroit	8.57	1.85	.....	11.53	100.00	.....
26	Golden Eye	8.31	1.08	.....	9.21	100.00	.....

TABLE III. *Susceptibility of different varieties of beans to rust infection, with infection on Tennessee Green Pod as standard and rated 100 per cent*—Continued

POLE BEANS, GREEN POD

Experiment No.	Variety.	Average leaf area.	Number of infections per square inch.		Percentage of infection.		
			Flecks.	Sori.	Total.	Abortive.	Fertile.
		Square Inches.					
29	McCaslan	7.04	.....	37.87	118.68	.....	118.68
20	Virginia Cornfield	4.11	.....	36.07	106.09	.....	106.09
32	Cut Short	5.30	.....	3.19	104.61	.....	104.61
11	Kentucky Wonder	7.46	.....	5.75	80.87	.....	80.87
28	Dutch Case Knife	5.89	.....	36.85	77.50	.....	77.50
9	Royal Corn	5.03	.....	146.04	66.97	.....	66.97
26	Powell's Prolific	5.90	.....	6.82	58.14	.....	58.14
28	Creaseback	4.03	.....	24.32	51.12	.....	51.12
1	Lazy Wife	7.21	.....	2.68	13.74	.....	13.74
1	Horticultural, Pole	9.78	.....	2.12	10.87	.....	10.87
13a	Brockton	10.95	0.21	.05	6.77	80.70	1.31
7	Tennessee Wonder	10.09	63.10	.68	54.91	98.93	.59
13a	Marblehead	8.76	.10	.01	2.86	90.00	.26

POLE BEANS, WAX POD

17	Golden Cluster	5.84	.....	4.80	71.22	.....	71.22
28	Kentucky Wonder Wax	5.73	.....	32.32	67.94	.....	67.94
21	Mont d'Or	9.60	3.81	.....	9.75	100.00	.....
20	Everbearing	9.80	.45	.....	1.32	100.00	.....
17	Indian Chief	10.52	.....	.....	.....	.....	.....

In general the flecks are visible some time before the sori are evident. Accompanying the inoculation of Tennessee Green Pod on January 20, described previously, in which 143 hours elapsed before the "anlage" of the sori were plainly visible, flecks were visible on Hodson Green Pod in 112 hours and on Improved Goddard and Tennessee Wonder in 123 hours.

On certain varieties the immediate results of the inoculation with urediniospores is seen in the production of telia or of mixed sori. This is particularly true of Black Valentine and of some of the wax-podded varieties, notably Challenge, Flagolet, Golden Eye, Pencil Pod, Keeney, Wardwell, and New Kidney.

The size of uredinia will vary to some extent on a given variety according to the degree of infection and crowding. The average size of the sorus on different varieties varies greatly, however, ranging from about 180 μ on Dwarf Black Wax to 600 μ on Tennessee Green Pod (compare A and B, Pl. 72, and *a* and *d*, Plate 69, B).

The duration of the incubation period is modified by environment, especially temperature, but in different varieties under similar conditions a variation of several days may occur. Such variations have

been noted repeatedly. In order to have more definite data on this point two plants each of 72 varieties were inoculated on March 29, 1920, and were held under similar conditions. Thirty-seven of the varieties produced uredinia only, 3 both uredinia and flecks, 27 flecks only, and 5 neither sori nor flecks. The number of days elapsing before the uredinial "anlage" were visible varied from 6 to 10 on different varieties, and the time of sporulation from 10 to 15 days. The "anlage" were visible on 6 varieties on the sixth day, on 9 varieties on the seventh day, on 22 varieties on the eighth day, on 1 on the ninth day, and on 2 on the tenth day. Sporulation ensued on 6 varieties on the tenth day, on 30 on the eleventh day, on 2 on the twelfth day, on 1 on the fourteenth, and on 1 on the fifteenth. The number of days between the appearance of the "anlage" and sporulation varied from two to five, the mean being three days. As a general rule the sorus develops more rapidly on the more susceptible varieties than on the more resistant. The flecks on the resistant varieties were visible, as a rule, sooner than the "anlage" on the susceptible varieties. Flecks were observed on 9 varieties on the fifth day, on 16 on the sixth day, on 4 on the seventh, and on 1 on the eighth.

RELATIVE SUSCEPTIBILITY OF BEAN VARIETIES

In our previous publication (*4*) a number of varieties of beans were classified according to their susceptibility to rust under field conditions. Four classes were recognized—rust-free, rust-proof, rust-enduring, and rust-susceptible. In this work we have attempted to obtain a more definite expression of susceptibility by using a susceptible variety as a standard and expressing the relative susceptibility of other varieties in terms of that standard. A standard dosage is employed and the relative susceptibility of a variety is indicated by the percentage of infection obtained, modified by the amount of flecking, the size of the sorus, and the length of the incubation period.

The determination of the degree of infection is based on the assumption that all varieties receive approximately the same number of urediniospores per unit area of leaf surface exposed as the standard. The resultant infection is then determined by count and is calculated as average number of infections per square inch. The number of sori obtained on Tennessee Green Pod is then rated 100 per cent, and the number of infections on the other varieties in the test is reduced to percentage of the standard. The percentage of infection is expressed as total infection (both sori and flecks), fertile infection (sori only), and abortive infection (flecks). Total infection and fertile infection are in terms of the standard, but abortive infection relates only to the variety in question and is the percentage of the total infections aborted on that variety. The details of this method are illustrated in Tables I and II. Table III is a summary of the experiments and shows the degree of infection obtained on the 64 varieties tested.

The varieties are grouped for convenience according to the dwarf or running habit and the color of the pod. Of the 46 varieties of dwarf or bush beans, 32 have green pods and 14 wax pods. Of the 18 varieties of pole beans, 13 have green pods and 5 wax pods.

The very marked variation in the susceptibility of the different varieties under the conditions of the experiments is evident. They are arranged in the different groups according to susceptibility to infection, the production of sori (percentage of fertile infection) being used as the basis for comparison in those varieties which produce sori rather than the percentage of total infection.

In Table IV the 64 varieties are grouped under the four classes, and the comparative susceptibility of the classes as a whole is shown. It is apparent that pole beans with green pods constitute the most susceptible class and bush beans with wax pods the least susceptible, that pole beans are more susceptible as a class than bush beans, and that green-pod varieties are more susceptible than wax-pod varieties.

Considering that the production of sori is an indication of greater susceptibility than the production of flecks, it is seen that 67 per cent (12 in 18) of the pole varieties produced sori unaccompanied by flecks as compared with 35 per cent (16 in 46) of the bush beans, while only 11 per cent of the former class produced flecks unaccompanied by sori as compared with 33 per cent of the latter class. Comparing green-pod varieties with wax-pod varieties, the percentage with sori only is 58 as against 11, and for flecks only the percentage is 11 as against 63. Comparing severity of infection on individual varieties, it is seen that the fertile infection was 50 per cent or more of the standard in 55 per cent of the pole varieties as against 15 per cent of the bush varieties, and in 33 per cent of the green pods as against 11 per cent of the wax pods.

TABLE IV.—*Susceptibility of different classes of bean varieties to rust*

	Bush.		Pole.	
	Green.	Wax.	Green.	Wax.
Number of varieties tested	32	14	13	5
Number bearing sori only	16	.....	10	2
Number bearing sori and flecks	11	4	3	.....
Number bearing flecks only	5	10	.....	2
Number showing no infection	.....	.....	.....	1
Number showing fertile infection 50 per cent or more of standard	7	.....	8	2

CORRELATION BETWEEN SEED CHARACTERS AND SUSCEPTIBILITY TO RUST

In order to determine whether susceptibility to rust is associated with any particular color pattern or shape of the seed, a study of the seed

characters of a number of varieties was made. The data on seed characters have been drawn largely from Jarvis (*6*), supplemented by observations when necessary. The details of this study are shown in Table V. Only two classes with respect to susceptibility are provided, the rust-enduring, rust-proof, and rust-free varieties all being classed as resistant. Although it is probably impossible to draw conclusions that would not be subject to exceptions, nevertheless the following general statements can be made for the 51 varieties included in the study. With respect to color, all solid red or red mottled beans are rust-resistant. With respect to shape, all marrow beans are rust-resistant. White beans seem to be more susceptible as a group than black or brown beans, and pea beans more so than medium or kidney.

VARIABILITY OF VARIETIES

It is of interest to note to what extent the individual plants of a variety differ in behavior to rust infection. Although the number of plants of a variety under observation in the experiments is not large enough to justify more than tentative conclusions, sufficient additional evidence from field trials is available to indicate that the stability or variability of a variety as indicated below is approximately correct. The majority of varieties studied were stable with respect to rust infection, all individuals responding in the same way. The standard used, Tennessee Green Pod, is especially reliable in this respect. Of the 340 plants inoculated in the experiments all developed sori, and not a single fleck was observed. The stable varieties are grouped as follows, according to the character of the response to inoculation.

TABLE V.—*Correlation between seed characters and susceptibility to rust*[1]

Color of seed.	Pea.	Medium.	Marrow.	Kidney.	Totals.
White	2/7	1/2	2/2	1/5	6/16
White, yellow eye	.....	.....	2/2	.....	2/2
Black	.....	2/3	1/1	.....	3/4
Brown	.....	1/1	2/2	3/5	6/8
Yellow, brown ring	.....	1/1	.....	1/1	2/2
Red	.....	.....	4/4	1/1	5/5
Red on fawn or buff ground	.....	.....	3/3	5/5	8/8
Pink	.....	0/1	.....	.....	0/1
Brown, purple, or black on fawn or buff ground.	.....	0/1	.....	4/4	4/5
Total	2/7	5/9	14/14	15/21	36/51

[1] The denominator shows the total number of varieties, the numerator the number that are rust-resistant.

ALL PLANTS PRODUCING SORI ONLY, NO FLECKS.—Pink, Snowflake, Navy Pea, Tepary, Pinto, Red Kidney, White Kidney, Full Measure, Round Six Weeks, Longfellow, Giant Stringless, McCaslan, Virginia Cornfield, Cut Short, Kentucky Wonder, Dutch Case Knife, Royal Corn, Powell's Prolific, Creaseback, Golden Cluster, and Kentucky Wonder Wax.

ALL PLANTS PRODUCING FLECKS ONLY, NO SORI.—Refugee, Early Mohawk, May Queen, Improved Goddard, California, Webber, Flagolet, Challenge, Wardwell, New Pearl, Hodson Wax, Detroit, Golden Eye, and Mont d'Or.

ALL PLANTS PRODUCING BOTH SORI AND FLECKS, THE SORI BORNE EITHER WITHIN THE FLECKS OR INTERMIXED WITH THEM.—Dwarf Black Wax, Burpee's Stringless, Tennessee Wonder, and Black Valentine.

ALL PLANTS CLEAN, PRODUCING NEITHER SORI NOR FLECKS.—Indian Chief.

The individual plants of the remaining 25 varieties were somewhat variable in response to rust inoculation. This is shown in Table VI. In the varieties Blue Pod Navy, Yellow Eye, Lady Washington, White Marrow, and Bird Eye, a large percentage of the individuals developed sori and a small percentage showed no infection, while these conditions were reversed in Lazy Wife. There were no intermediate or flecking plants in any of these.

TABLE VI.—*Response of individual plants of unstable varieties to rust inoculation*

Variety.	Percentage of plants showing—			
	Sori only.	Sori and flecks.	Flecks only.	Clean.
Blue Pod Navy	95	.....	.....	5
Yellow Eye	95	.....	.....	5
Emerald Beauty	90	10	.....	.....
Lady Washington	90	.....	.....	10
White Marrow	90	.....	.....	10
Bird Eye	90	.....	.....	10
May Queen	60	40	.....	.....
Horticultural Pole	55	5	5	35
Bountiful	50	25	25	.....
Horticultural Dwarf	45	.....	5	50
Red Valentine	40	55	.....	5
Warren	35	10	55	.....
French's Horticultural	30	70	.....	.....
Keeney	30	70	.....	.....
Brockton	20	.....	50	30
Currie	10	65	25	.....
Early Refugee	10	10	60	20
Marblehead	10	10	40	40
Mexican Red	10	.....	50	40
Lazy Wife	5	.....	.....	95
Scarlet Wax	.....	90	10	.....
Low's Champion	.....	40	60	.....
Hodson Green Pod	.....	5	95	.....
Everbearing	.....	.....	20	80

The greatest variability is shown in the varieties Horticultural Pole, Horticultural Dwarf, Brockton, Early Refugee, Marblehead, and Mexican Red. All had a considerable percentage of clean plants, some that developed sori, and some intermediates.

SIZE OF THE SORUS AS AN INDEX OF SUSCEPTIBILITY

In addition to the degree of infection and the production of flecks, the size of the sorus produced on different varieties also provides an index of relative susceptibility. As noted previously, great variation exists in the size of the sori produced on different varieties. The size of the sorus in turn is an index to the spore production of the sorus, and any marked curtailment in the number of spores produced may readily be conceived to be a limiting factor of considerable importance in the propagation of the pathogene. The production of a small sorus is evidently to be considered in the same light as the production of flecks—as a response to an unfavorable medium.

The average size of the uredinium on each variety has been determined by measurement of a number of uredinia. The relative spore-producing capacity is then determined by calculating the number of urediniospores produced in a layer one spore in thickness covering the sorus. This does not represent the total spore-producing capacity of the sorus but gives a basis for comparison between varieties. The main objection to this expression is that it does not magnify the differences between the more susceptible and more resistant varieties sufficiently. It seems evident from examination that the more susceptible varieties produce more layers of spores in a uredinium than the more resistant ones. No differences have been found in the size of the urediniospores borne on different varieties.

In determining the number of spores produced by a sorus, the number in the diameter is determined by calculation. The urediniospore is approximately 20 μ in diameter, and 30 such spores would be contained in the diameter of a sorus 600 μ broad. The square of the number in the diameter multiplied by 0.7854 gives the number in one layer covering the sorus. The sorus on Tennessee Green Pod, which is one of the largest, averages 600 μ in diameter and, therefore, has a spore-producing capacity of 706.8 spores in one layer, while that on Bird Eye, averaging 300 μ, has a spore-producing capacity of only 176.7. The spore-producing capacity of the sorus on different varieties has been reduced to percentages for purposes of comparison. The sorus on Tennessee Green Pod is again used as the standard, and its spore-producing capacity is rated 100 per cent. The varieties on which data were obtained are grouped in Table VII according to spore production.

It will be noted in a comparison between Tables VII and III that varieties with high rating in percentage of fertile infection also show rate high in spore-producing capacity. Tepary is the only variety rating above 50

per cent in fertile infection which falls below 50 per cent in spore-producing capacity, while three varieties, White Marrow, Full Measure, and Keeney's Rustless, rating below 50 per cent in fertile infection, have spore-producing capacities in excess of 50 per cent. In general it can be stated that the production of large sori is an indication of greater susceptibility to infection than the production of small sori.

TABLE VII.—*Relative spore-producing capacity of the uredinia on different varieties*

Spore-producing capacity.		Variety.
Per cent.	Number.	
100	707	Tennessee Green Pod, Navy Pea, Snowflake, Lady Washington, McCaslan, Virginia Cornfield, Dutch Case Knife, Powell's Prolific, Creaseback, Cut Short, Golden Cluster.
70	491	Pinto, White Marrow, Kentucky Wonder, Royal Corn.
54	380	Pink, Red Valentine, Full Measure, Keeney's Rustless.
44	314	Tepary, Blue Pod Navy, Red Kidney, White Kidney, Horticultural Dwarf, Round Six Weeks, Longfellow, Low's Champion, Brockton, Tennessee Wonder, Kentucky Wonder Wax.
32	227	Early Refugee, Giant Stringless, Bountiful, Horticultural Pole.
25	177	Warren, Bird Eye, French's Horticultural, Black Valentine, Marblehead, Currie.
16	113	Yellow Eye, Burpee's Stringless, Mighty Nice, Mexican Red.
11	79	Scarlet Wax, Crystal White, Dwarf Black.

SUSCEPTIBILITY OF BEAN VARIETIES UNDER GREENHOUSE CONDITIONS AS COMPARED WITH FIELD CONDITIONS

The question is naturally raised in connection with greenhouse experiments as to what extent they serve as a reliable index of field behavior. All the varieties of beans used in our greenhouse work have been grown in the field, most of them during two seasons, where they have been subjected to uniform exposure to rust infection by inoculation. The results of the first season's field tests have been described in a previous paper (*4*). In the 1918 tests the varieties were classified according to relative susceptibility in four groups, as follows: Susceptible, rust-enduring, rust-proof, rust-free. Yields were obtained only for the dwarf varieties commonly grown for dry-shell purposes and from the pole beans. In the 1919 tests some of the most susceptible varieties were eliminated and some additional varieties were added. This season was particularly favorable for the development of anthracnose, and some of the varieties suffered severe losses from this disease and to a lesser degree from bacterial blight. With respect to rust infection, the varieties respond in the same way during the two seasons, but the effects

of the rust attack were not so noticeable in 1919 as in 1918. The susceptible varieties were severely rusted, but defoliation was not so severe until later in the season, and their yield was better in comparison with that of the more resistant varieties than in 1918. No data on the curtailment of the yield of the pole varieties as determined by rust infection could be obtained because of the severity of anthracnose on certain varieties.

The greenhouse and field behavior of the dry-shell varieties is compared in Table VIII, and that of the pole varieties in Table IX. The varieties are listed according to susceptibility in the greenhouse.

Of the 17 varieties in Table VIII the first 7, which were classed as susceptible in the field, all rated above 70 per cent fertile infection in the greenhouse, while the 9 varieties in the resistant classes—enduring, proof, and free—all fell below 50 per cent fertile infection. Robust, not included in the greenhouse tests, was classed as rust-proof in the field and outyielded all other varieties in 1919. This is the only small white bean in our tests, with the exception of Blue Pod Navy, which has successfully withstood the attack of rust. Robust seems to be an especially desirable variety in that it combines resistance to mosaic, as shown by Reddick and Stewart (*9*), with rust resistance, attractive appearance, and desirable commercial type. Bird Eye, grown for the first time in 1919, was classed as rust-free and was second to Robust in yield. This variety is similar to Yellow Eye in seed characters and is popular in some localities in Virginia. It is attractive and of good quality and seems to be very dependable. The yields in 1918 are more representative of the curtailment of production by rust than those in 1919, since anthracnose was severe in the latter year. The yields of Improved Goddard, Horticultural Dwarf, and White Kidney were reduced materially by anthracnose. Bird Eye and Well's Red Kidney were especially free from anthracnose. Robust was quite free from anthracnose in 1919 but was severely injured in 1920.

Of the 18 varieties of pole beans listed in Table IX the 8 which were classed as susceptible all exceeded 50 per cent fertile infection in the greenhouse. All the rust-proof and rust-free varieties fell below 50 per cent; but the two rust-enduring varieties, Golden Cluster and Kentucky Wonder Wax, rated 71 and 68 per cent. The yield of all of the susceptible varieties was severely curtailed by the rust attack in 1918, 5 of them being complete failures (Pl. 71, A). McCaslan was not grown in 1918 but was seriously damaged in 1919. No yield data for 1919 are given, as explained previously, because of the severity of anthracnose. This injury was especially severe on Indian Chief, Everbearing, Mont d'Or, Marblehead, Brockton, and Lazy Wife.

TABLE VIII.—*Comparison between greenhouse and field behavior of dry-shell beans*

Variety.	Percentage of fertile infection in greenhouse.	Field.			
		Susceptibility to rust.	Yield of dry beans.		Severity of anthracnose.
			1918.	1919.	
			Gm.	*Gm.*	
Pink	120	Susceptible	[a] 14	.....	
Snowflake	116	do	[a] 386	.....	
Navy Pea	111	do	[a] 313	[a] 2,390	Slight.
Tepary	101	do	[a] 0	.....	
Tennessee Green Pod	100	do	[a] 270	.....	
Pinto	89	do	[a] 153	.....	
Lady Washington	74	do	[a] 633	[a] 2,174	Do.
Robust	[c]	Proof	.....	9,976	None.
Blue Pod Navy	44	Enduring	1,121	4,370	Moderate.
Red Kidney	39	Free	1,852	4,085	None.
White Kidney	33	do	682	[b] 2,960	Severe.
White Marrow	25	Enduring	1,119	4,024	Slight.
Horticultural Dwarf	19	Proof	1,305	[b] 2,730	Very severe.
Bird Eye	9	Free	.....	4,918	None.
Yellow Eye	7	Proof	938	3,250	Slight.
Mexican Red	−1	Free	1,090	3,185	Moderate.
Improved Goddard	−1	do	618	[b] 1,310	Very severe.

[a] Yield reduced materially by rust.
[b] Yield reduced materially by anthracnose.
[c] Not tested.

TABLE IX.—*Comparison between greenhouse and field behavior of pole beans*

Variety.	Percentage of fertile infection.	Field rating.	Yield in 1918.	Severity of anthracnose in 1919.
			Gm.	
McCaslan	119	Susceptible	.....	Slight.
Virginia Cornfield	106	do	0	
Cut Short	105	do	0	
Kentucky Wonder	81	do	109	Moderate.
Dutch Case Knife	78	do	159	Slight.
Golden Cluster	71	Enduring	263	Do.
Kentucky Wonder Wax	68	do	216	Do.
Royal Corn	67	Susceptible	0	
Powell's Prolific	58	do	0	Do.
Creaseback	51	do	0	
Lazy Wife	14	Variable	.....	Very severe.
Horticultural Pole	11	Proof	897	Slight.
Brockton	1	Free	556	Very severe.
Tennessee Wonder	−1	Proof	751	
Marblehead	−1	Free	371	Severe.
Mont d'Or	0	do	506	Very severe.
Everbearing	0	do	143	Do.
Indian Chief	0	do	261	Do.

There is in general a very satisfactory agreement between the greenhouse and field behavior of bean varieties; and the greenhouse test, properly interpreted, seems to afford a reliable basis for predicting the

relative susceptibility of a variety in the field. The greenhouse test is seemingly a more severe one than the field test. Some varieties which have developed a few sori in the greenhouse have remained entirely rust-free in the field. It seems to hold true that a variety which develops less than 50 per cent fertile infection in the greenhouse does not suffer material injury from rust in the field, and conversely that a variety which exceeds 50 per cent infection in the greenhouse may be expected to suffer material injury in the field. No exceptions to the first rule have been noted and only two apparent exceptions, Golden Cluster and Kentucky Wonder Wax, to the latter. Both these varieties were conspicuously rusted in the field, but both yielded fair crops. It is impossible to state the degree of injury sustained by these varieties, since no rust-free plants were available for comparison.

CURTAILMENT OF YIELD DUE TO BEAN RUST

Attempts have been made to obtain data on the amount of reduction in yield caused by bean rust, but the nature of the pathogene makes the securing of reliable data almost impossible. Yield data from rusted and rust-free plants should preferably be obtained from alternating rows in the same plot, but it is impossible to maintain rust-free plants of susceptible varieties in the same plot with rusted plants. It was thought that the difficulty might be overcome by growing both resistant and susceptible varieties in separate isolated rusted and rust-free plots, the resistant varieties being used as a criterion of the relative crop-producing capacities of the different soils.

A planting of this type was made in 1918 with Improved Goddard as the resistant variety and Navy Pea and Tennessee Green Pod as the susceptible varieties. The soil of the two plots was similar in physical properties and apparently so in fertility. All plants in the rusted plot were inoculated with urediniospores, and a general and severe infection resulted on the rows of susceptible varieties. The rust-free plot was not inoculated. It became infected naturally later in the season but not early enough to cause any material reduction in yield. Unfortunately the rust-resistant variety was so severely attacked by anthracnose that no reliable yield data could be obtained. The difference in growth and yield of the rust-susceptible varieties on the two plots was very marked, almost no beans being produced in the rusted plot. The yields of shelled beans for single rows 65 feet in length were as follows: Tennessee Green Pod, rust-free plot 267 gm., rusted plot 9 gm., difference 95 per cent; Navy Pea, rust-free plot 494 gm., rusted plot 95 gm., difference 81 per cent.

A similar test was made in 1920 with three susceptible and three resistant varieties. The two plots were on the same piece of land but were separated by a strip of corn. Rust was very abundant on the susceptible varieties in the inoculated plot, while the control remained free

throughout the season. The injury from rust was not so great as in 1918, apparently on account of seasonal differences; and the plants in the rusted plot retained their leaves longer and matured a fair crop. The yields are shown in Table X. The figures are in grams of shelled beans for single rows 60 feet in length and are averages of two rows for each variety. It will be noted that the three susceptible varieties all show a decrease in yield on the inoculated plot, while the three resistant varieties show an increase. It seems from this that the soil of the inoculated plot was better and that greater differences in the yield of the rusted and rust-free rows of susceptible varieties would be expected on plots of equal fertility. The three susceptible varieties show an average decrease of 28 per cent in the inoculated plot, while the three resistant varieties show an average increase of 31 per cent. It seems apparent that a reduction in yield of 50 per cent or more may be expected from a severe rust attack on susceptible varieties.

TABLE X.—*Yields of rust-susceptible and resistant varieties of beans in rusted and rust-free plots*

Variety.	Susceptibility to rust.	Rust-free plot.[1]	Rusted plot.[1]	Yield of rusted plot in percentage of rust-free plot.
Tennessee Green Pod	Susceptible	970	530	55
Pinto	do	385	217	56
Navy Pea	do	1,007	959	95
Bird Eye	Resistant	2,243	2,325	104
Yellow Eye	do	1,466	2,091	143
Red Kidney	do	2,162	3,256	151

[1] Expressed in grams per 60-foot row.

BIOLOGIC FORMS OF BEAN RUST

We have made no extended study of the occurrence of biologic forms of the bean-rust fungus, but it seems desirable to record such observations as have been made in connection with the studies on susceptibility of varieties.

The strain of rust from the kidney or garden bean which we have used in our studies has been tested on a large number of horticultural varieties of the kidney bean (*Phaseolus vulgaris*), on 9 varieties of the lima bean, (*P. lunatus* L.), 1 variety of the tepary bean (*P. acutifolius latifolius* D. F. Freeman), 18 varieties of cowpeas (*Vigna sinensis* (L.) Endl.), 1 variety of the broad or horse bean (*Vicia faba*), and 1 variety of asparagus bean (*Dolichos sesquipedalis* L.). Infection has resulted on many varieties of the kidney bean, as recorded previously, and also on the tepary bean. Slight infection only was obtained on 1 variety of lima bean in the greenhouse, but the other 8 varieties tested remained free from infection in both greenhouse and field. The infection in this case was slight and con-

sisted of small telia borne in the centers of flecks. No infection was obtained on the horse bean, the asparagus bean, nor on any variety of cowpea.

A second form distinct pathologically from the foregoing but similar morphologically was isolated in 1919 from leaves of cowpeas, variety Black Eye, which were sent us from California by Mr. D. C. Milbrath. It has been cultured in the greenhouse on plants of this variety and has been used for both greenhouse and field inoculations on a number of varieties of kidney beans and 18 varieties of cowpeas. Infection has been obtained on only the Black Eye variety of cowpea and on two similar strains, Extra Early Black Eye and Ramshorn Black Eye. No tests have been made on lima, horse, tepary, or asparagus beans.

These two strains may be designated the kidney-bean strain and the cowpea strain. They are distinct biologically, but their host ranges are as yet imperfectly known. It is possible that more than one biologic form occurs on kidney beans, but such evidence as is at hand would indicate that the strain which occurs commonly on kidney beans in the United States has the same host preferences as the one we have studied. The behavior of varieties in Maine, as observed by Morse (*9*), agrees in all essentials with our data, and the general mention of rust on Kentucky Wonder in other States points to this conclusion. It seems probable that a distinct biologic form occurs in South America. Gassner (*5*) records rust as severe on Mont d'Or and Flageolet, two-wax-pod varieties, while our strain produced flecks only on these. It is possible, however, that the varieties grown under these names by us were distinct from those used in South America. Gassner obtained his seed from Europe.

SUMMARY

A technic of inoculation and method of record is described which makes possible the expression of the relative rust susceptibility of varieties of beans in terms of percentage of a standard.

Variations from the behavior of the susceptible standard which occur in different varieties following inoculation with urediniospores in the greenhouse are of the following types: (*a*) reduction in number of infections, (*b*) reduction in the size of the uredinium, (*c*) abortion of infection or flecking, (*d*) immediate production of telia instead of uredinia, (*e*) lengthening of the incubation period. These variations are considered as responses to an unfavorable medium and as expressions of resistance.

Of the varieties studied, those with indeterminate growth (pole beans) were more susceptible as a class than those with determinate growth (bush beans). Green-pod varieties were more susceptible as a class than wax-pod varieties. With respect to color of seed all varieties with solid red or red mottled seed were rust resistant, while varieties with white seed were more susceptible as a class than those of any

other color. With respect to form of seed all varieties of the marrow type were rust resistant and those with pea beans constituted the most susceptible class.

Little or no variation in the susceptibility of individuals was found in the majority of the varieties studied, but marked variation existed between individuals in a few varieties.

Field tests which have supplemented the greenhouse tests have demonstrated that the greenhouse test affords a reliable index of the field behavior of a variety with respect to rust infection. An attack of rust on susceptible varieties in the field may result in a curtailment of production amounting to 50 per cent or more, and in very severe attacks to total loss.

The existence of two biologic forms of the bean-rust fungus has been demonstrated, but their host ranges are as yet imperfectly known.

LITERATURE CITED

(1) Arthur, Joseph Charles.
1907–1912. UREDINALES. *In* North American Flora, v. 7, no. 2, p. 83–160; no. 3, p. 257.

(2) Duggar, Benjamin Minge.
[1909]. FUNGOUS DISEASES OF PLANTS. 508 p., 240 fig. Boston.

(3) Fromme, F. D.
1913. THE CULTURE OF CEREAL RUSTS IN THE GREENHOUSE. *In* Bul. Torrey Bot. Club, v. 40, no. 9, p. 501–521. Literature, p. 519–521.

(4) ——— and Wingard, S. A.
1918. BEAN RUST. Va. Agr. Exp. Sta. Bul. 220, 18 p., illus.

(5) Gassner, Gustavo.
1909. ALGUNAS OBSERVACIONES SOBRE EL "POLVILLO" DE LOS POROTOS (UROMYCES APPENDICULATUS). *In* Rev. Secc. Agron. Univ. Montevideo, no. 4, 1908, p. 125–129, illus.

(6) Jarvis, C. D.
1908. AMERICAN VARIETIES OF BEANS. N. Y. Cornell Agr. Exp. Sta. Bul. 260, p. 149–255, illus., 16 pl. (1–3 col.).

(7) Jordi, Ernst.
1916. ÜBER DIE EMPFÄNGLICHKEIT VON PHASEOLUS VULGARIS L. FÜR BOHNENROST. *In* Ztschr. Pflanzenkr., Bd. 26, Heft 6/7, p. 374–375.

(8) Melhus, I. E., and Durrell, L. W.
1919. STUDIES ON THE CROWN RUST OF OATS. Iowa Agr. Exp. Sta. Research Bul. 49, 144 p., 6 fig. Bibliography, p. 143–144.

(9) Morse, W. J.
1918. RUST CAUSED BY UROMYCES APPENDICULATUS. MAINE. *In* U. S. Dept. Agr. Bur. Plant Indus. Plant Disease Bul., v. 2, no. 10, p. 174.

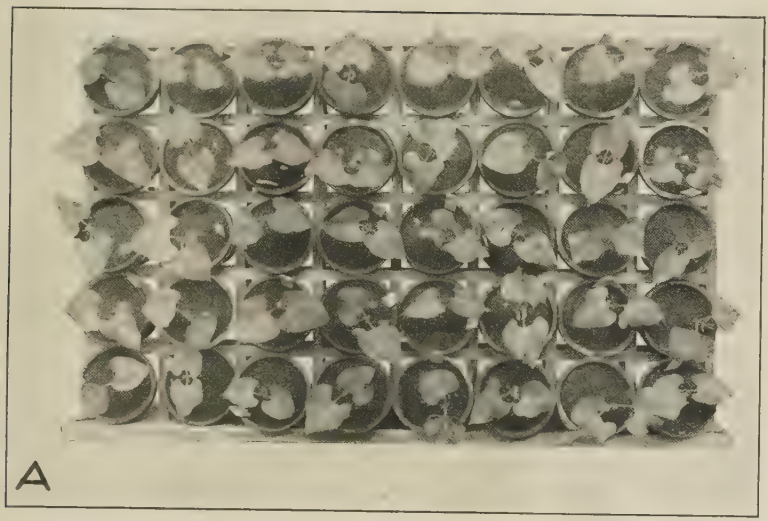
(10) Reddick, Donald, and Stewart, Vern B.
1918. VARIETIES OF BEANS SUSCEPTIBLE TO MOSAIC. *In* Phytopathology; v. 8, no. 10, p. 530–534.

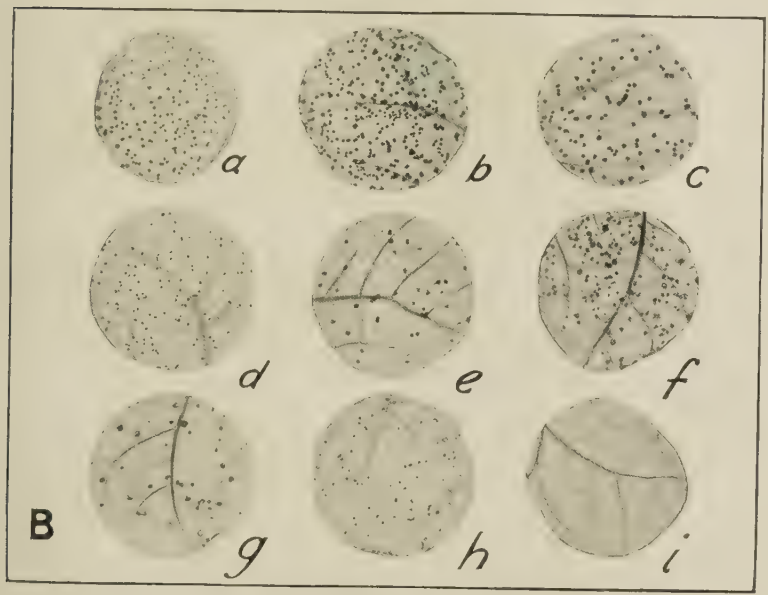
(11) Smith, Ralph E.
1914. PLANT PATHOLOGY. *In* Calif. Agr. Exp. Sta. Rept. 1913/14, p. 139–142.

PLATE 69

A.—The frame used in the inoculation of bean plants in the greenhouse, filled with plants in position for atomization.

B.—Disks of leaves of varieties of beans photographed after extraction of chlorophyll, showing variation in response to rust inoculation in the greenhouse. All inoculated at the same time and incubated under similar conditions. *a*, Tennessee Green Pod, large uredinia; *b*, McCaslan and *c*. Navy Pea, similar to *a; d*, Yellow Eye, small uredinia; *e*, French's Horticultural, small uredinia bordered by flecks; *f*, Tennessee Wonder, small uredinia, uredinia bordered by flecks and flecks, *g*, New Pearl, large flecks; *h*, Improved Goddard, small flecks; *i*, Horticultural Pole, neither sori nor flecks.


A


a
b
c
d
e
f
B
g
h
i

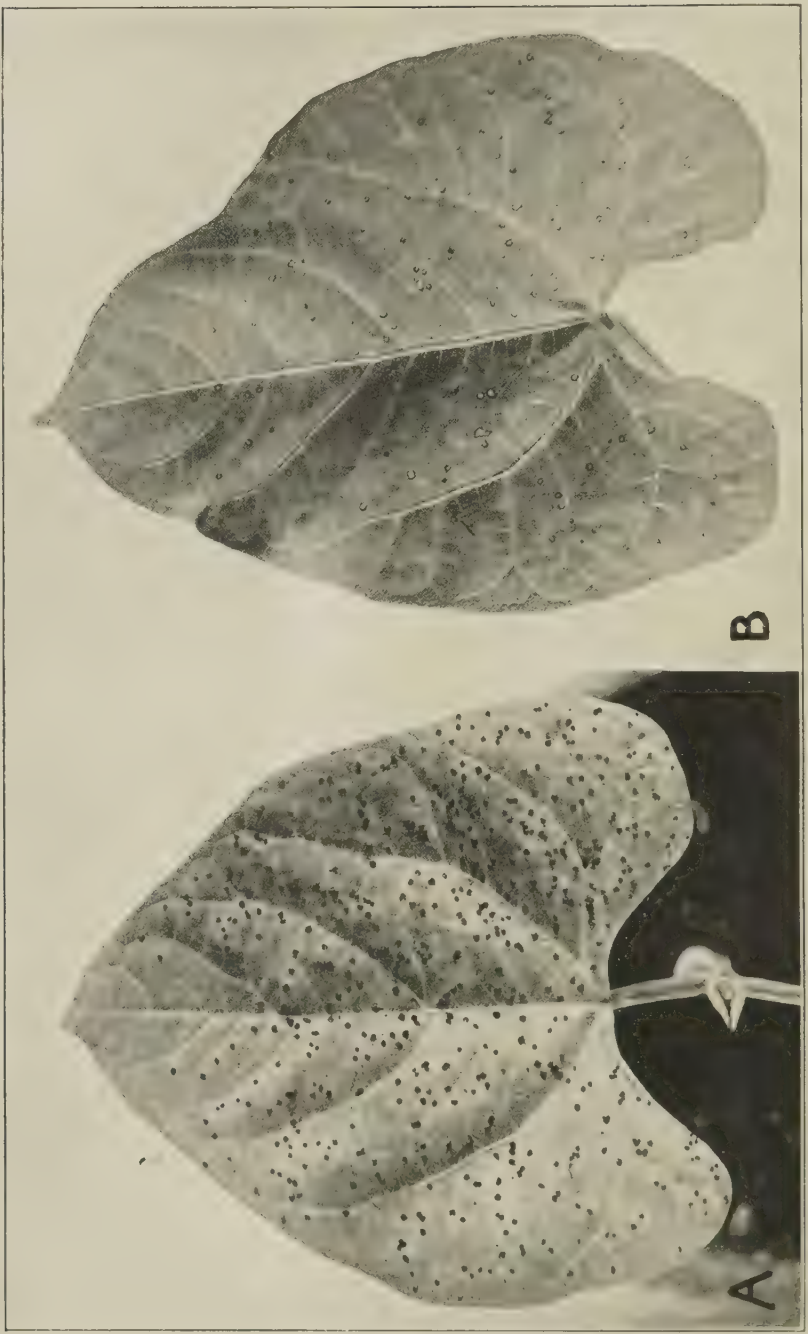

B
A

PLATE 70

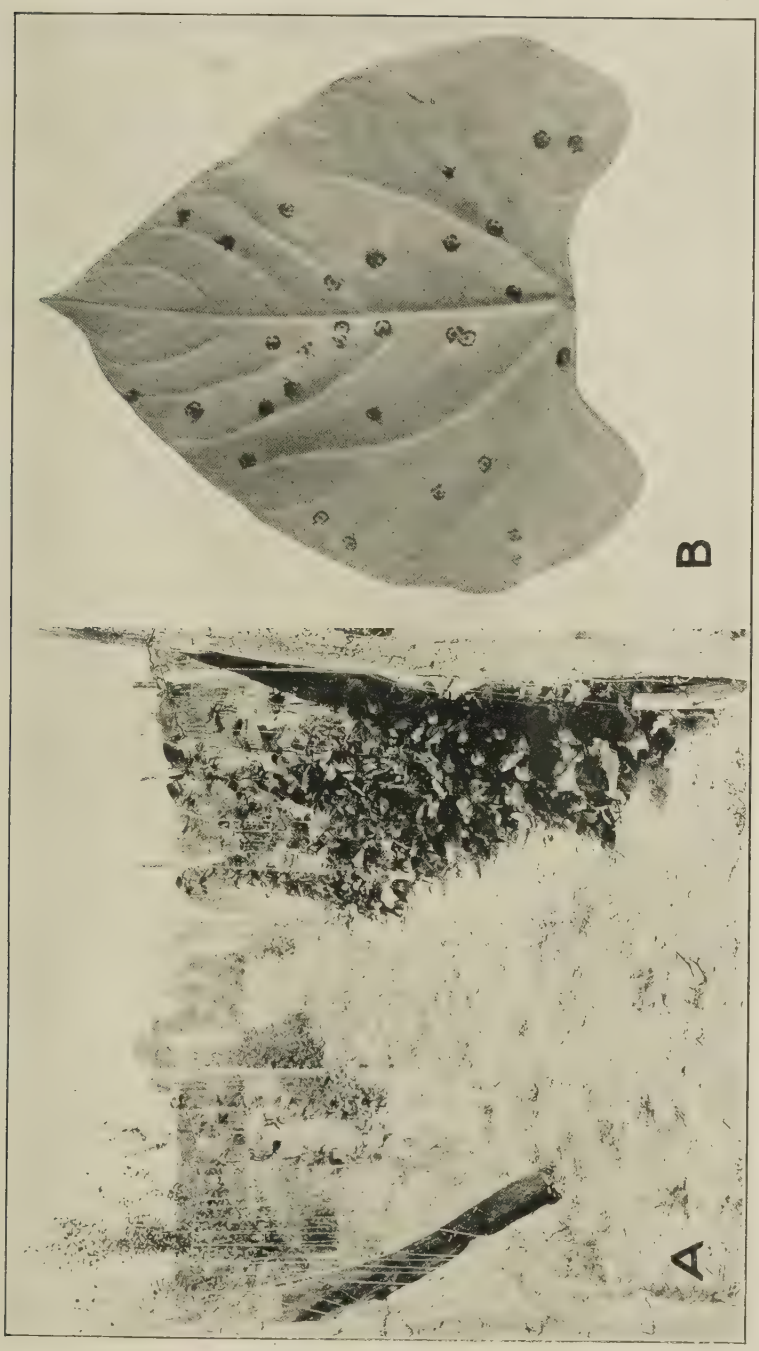
A.—Normal rust infection on a leaf of Dutch Case Knife developed in the greenhouse. Number of uredinia 544, leaf area 7.93 square inches, sori per square inch 68.6. Photographed 16 days after inoculation. Approximately natural size.

B. Abortive rust infection on a leaf of Improved Goddard. Number of flecks 140, leaf area 10.78 square inches, flecks per square inch 12.9. Photographed 16 days after inoculation. Approximately natural size.

PLATE 71

A.—Comparison of varietal susceptibility of beans to rust in the field. Left Powell's Prolific, susceptible, completely defoliated from rust infection. Right Tennessee Wonder, resistant, uninjured by rust. Photographed August 13, 1918.

B.—Secondary uredinia formed in circles around the primary uredinia on a leaf of Tennessee Green Pod. Photographed one month after inoculation in the greenhouse. Slightly reduced.


B
A

B
A

PLATE 72

Contact prints of bean leaves showing comparative sizes of uredinia:

A.—Tennessee Green Pod. Average diameter of uredinia 600 μ, spore-producing capacity 100 per cent. Natural size.

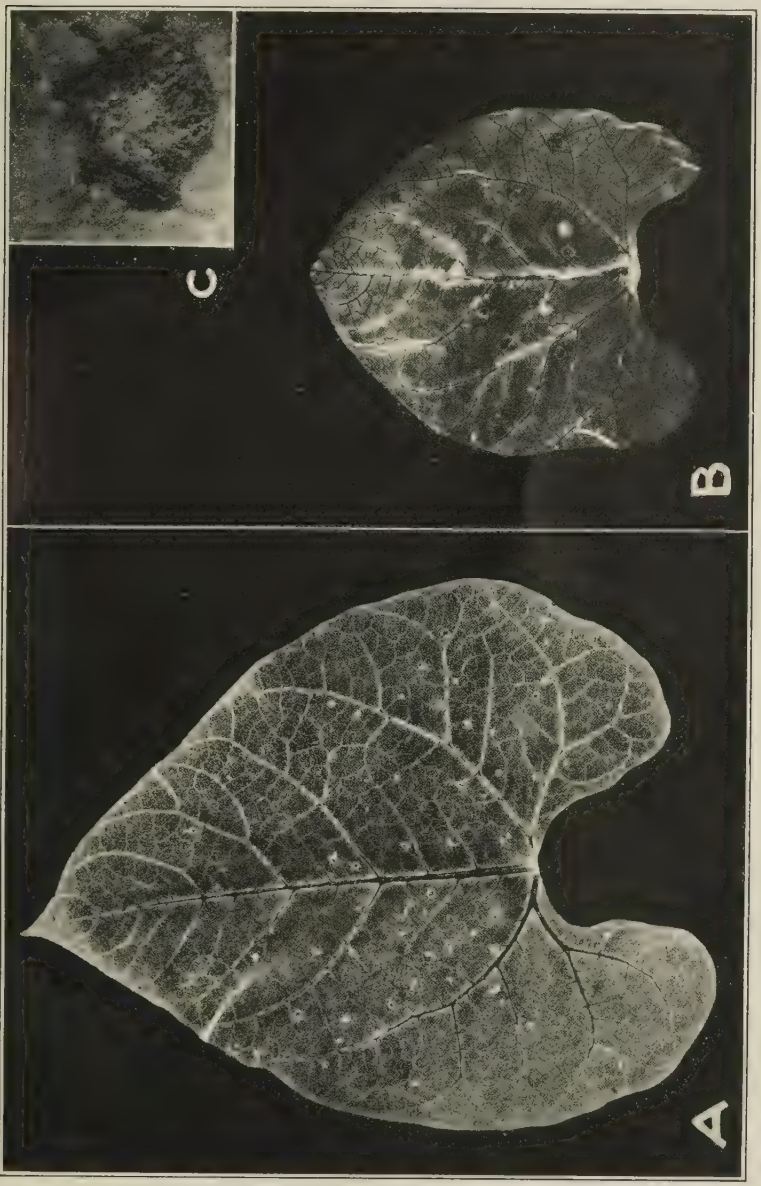
B.—Burpee's Stringless. Average diameter of uredinia 240 μ, spore-producing capacity 16 per cent. Natural size.

PLATE 73

A.—Contact print of a leaf of Mighty Nice showing small, angular flecks. Natural size.

B.—Contact print of a leaf of Crystal White showing unusually large, rounded flecks. Natural size.

C.—A typical fleck on a leaf of Tennessee Wonder. Approximately × 20.


C
B
A